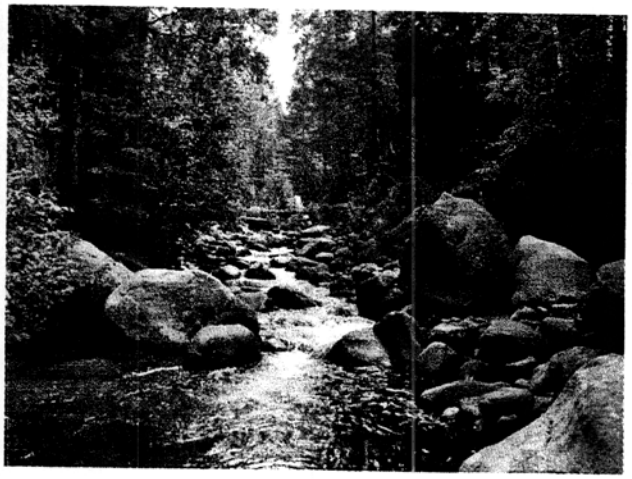

A Conference on Water Quality Monitoring II

Turbidity and Suspended Sediment Sampling

Tuesday, April 26, 2005
Holiday Inn, Redding, California

Co-sponsored by:
California Department of Forestry and Fire Protection &
University of California, The Center for Forestry

Conference Goals:

- Discuss past and present research and monitoring projects
- Begin to develop a common understanding and agreement on monitoring parameters and protocols
- Explore the possibility of creating a forum in California to meet annually and share ongoing research and monitoring findings.

Agenda

Tuesday, April 26, 2005

7:45 a.m. **Introduction**—*Cajun James,* Sierra Pacific Industries, Redding

MONITORING GEOMORPHIC AND BIOLOGICAL CHANGE & QA/QC PROTOCOLS

8:00 - 9:00 **KEYNOTE SPEAKER: Sediment Yield on Timescales From Minutes to Millions of Years**—*James W. Kirchner*, University of California, Berkeley

9:00 - 9:25 **The Effect of Turbidity on the Efficiency of Prey Capture by Juvenile Salmonids**—*Ken Cummins*, Humboldt State University

9:25 - 9:50 **The Role of Organic Suspended Sediment in Turbidity Studies**—*Mary Ann Madej,* US Geological Survey

9:50 -10:15 **It's a Long Way From Reactive Distance to Populations: Estimating the Consequences for Fish of Variation in Turbidity Regimes**—*Bret Harvey*, USFS Redwood Sciences Laboratory

10:15 -10:30	Break
10:30 -10:55	**A Review of Instrumentation, Data Collection Methods, and Quality Assurance Procedures**—*Rand Eads*, USFS Redwood Sciences Laboratory
10:55 -11:20	**New USGS Turbidity Methods and Data-Reporting Procedures**—*Timothy G. Rowe,* US Geological Survey
11:20 -11:45	**Challenges and Opportunities in Pooling Turbidity Data**—*Randy Klein*, Redwood National and State Parks
11:45 -12:10	**Using Multi-Parameter Water Quality Instruments to Perform Continuous Monitoring**—*Bob Nozuka,* Central District, California Dept. of Water Resources
12:10 - 1:00	Lunch

CASE STUDIES IN MONITORING SUSPENDED SEDIMENT AND TURBIDITY

1:00 - 1:25	**Connecting Watershed Sediment Budgets and Sediment Yield With Turbidity Monitoring—Case Studies From PALCO Lands on the North Coast of California**—*Kate Sullivan,* PALCO
1:25 - 1:50	**Grab Sample What-ifs in the Context of Event-Based Suspended Sediment Monitoring on Little Creek, Swanton Pacific Ranch – Cal Poly**—*Brian Dietterick,* Cal Poly, San Luis Obispo
1:50 - 2:15	**Suspended-Sediment Loads to Lake Tahoe**—*Andrew Simon*, USDA-ARS National Sedimentation Laboratory
2:15 - 2:30	Break
2:30 - 2:55	**Judd Creek Watershed Study: Results, Measurement Protocols and Assessment Methods**—*Cajun James*, Sierra Pacific Industries
2:55 -3:20	**Turbidity Tales at Multiple Scales: Water Quality Monitoring on the Hawthorne Ownership, Mendocino County**—*Stephen P. Levesque,* Campbell Timberland Management
3:20 - 3:45	**Why Monitor Turbidity: Is There a Connection Between Turbidity and Fish Populations?**—*Matthew R. House*, Green Diamond Resource Co.
3:45 - 5:00	**Discussion on Implementation Procedures of Water Quality Monitoring for Timber Harvest Plans and Research Issues**—Moderator *Cajun James* *James W. Kirchner*, University of California, Berkeley, to lead Q&A and panel discussion; George Ice will be available to answer questions regarding water quality monitoring in other western states
5:00	Conference Closes

Many Thanks to Our Exhibitors

Forest Technology Systems Ltd., Tom Vandall, 250-478-5561, tvandall@ftsinc.com
Sharman Company, Dan Keane, 510-410-0217, dkeane@sharmancompany.com
YSI, Environmental Inc., David Lee, 916-421-5199, dlee@ysi.com

A Conference on Water Quality Monitoring II

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MONITORING GEOMORPHIC AND BIOLOGICAL CHANGE & QA/QC PROTOCOLS

KEYNOTE SPEAKER: Sediment Yield on Timescales From Minutes to Millions of Years

James W. Kirchner, University of California, Berkeley

Abstract: Documenting rates, patterns, and processes of erosion is crucial for understanding how mountainous regions evolve, for managing the erosional effects of land use, and for understanding how sediment loading affects stream ecosystems. Our understanding of erosional processes is being transformed by measurements of erosion and sediment transport rates across timescales spanning at over 12 orders of magnitude, from minutes to millions of years. These measurements show that in some mountainous settings, erosion processes are highly episodic across multiple timescales. These observations imply that measurements at one timescale cannot be readily extrapolated to another. In particular, the episodicity of erosion and sediment transport makes long-term averages difficult to define and difficult to measure. These issues are illustrated with several case studies.

At an abandoned mine in Marin County, we monitored mercury concentrations and sediment fluxes downstream of an eroding waste pile in order to quantify the flux of mercury being discharged to a nearby estuary. Mercury concentrations varied over 2000-fold, from ~500 to ~1,000,000 ng/L, grossly exceeding the regulatory water quality objective of 12 ng/L in every case. Particulate mercury represented over 99.97% of the total mercury, and total mercury was tightly correlated ($r=0.98$) with suspended sediment concentrations. Thus we could estimate a continuous record of mercury fluxes from continuous measurements of discharge (using a small flume) and turbidity (using an optical backscatter sensor). In a two-month period, this small mine site discharged approximately 82 kg of mercury. Sediment and mercury fluxes were strongly associated with storm events; as a result, more than 75% of the total mercury flux occurred in less than 10% of the total time. In systems such as this one, where contaminant transport is highly episodic, sampling programs that miss the high-flow episodes may greatly underestimate the actual water quality threat. In addition, changes in pollutant fluxes or concentrations in receiving waters may not reflect changes in pollutant sources (such as remediation efforts) if the stochastic forcing (such as intense rainstorms) varies through time. In highly stochastic systems, water quality trends may be more accurately measured by changes in the contaminant rating curve, rather than changes in fluxes themselves (Whyte and Kirchner, Science of the Total Environment 260, 1-9, 2000).

We used cosmogenic ^{10}Be to measure erosion rates over 10 000-yr time scales at 32 Idaho mountain catchments, ranging from small experimental watersheds (0.2 km^2) to large river basins (35,000 km^2). These long-term sediment yields were, on average, 17 times higher than stream sediment fluxes measured over 10-84 yr, but were consistent with 10^7-yr erosion rates measured by apatite fission tracks (Kirchner et al., Geology 29, 591-594, 2001). Methodological differences cannot explain the mismatch between short-term and long-term erosion rates; our cosmogenic nuclide methods are accurate when benchmarked against sediment yields over 10,000-year timescales (Granger et al., J. Geol. 104, 249-257, 1996). Nor are climatic changes likely to be responsible; measurements across climatically diverse Sierra Nevada sites show that long-term erosion rates vary by only a factor of 2.5 and are not correlated with climate, even though mean temperatures vary by 11 C and precipitation varies nearly 9-fold (Riebe et al., Geology 29, 447-450, 2001).

Instead, we hypothesize that long-term average erosion rates are dominated by catastrophic erosion events that are too rare to be reliably observed in typical sediment yield studies. For example, one of our sites was monitored with sediment traps for over 20 years, but the total sediment yield over this entire period was dwarfed (by 70-fold) by a single debris flow several years later. These observations imply that conventional sediment-yield measurements--even those made over decades--can greatly underestimate long-term average rates of sediment delivery. Our observations suggest that mountain erosion and sediment delivery to streams can be extremely episodic, subjecting aquatic ecosystems to catastrophic disturbance. Further work is needed to quantify how factors like fire and land use affect the risk of catastrophic erosion events.

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The Effect of Turbidity on the Efficiency of Prey Capture by Juvenile Salmonids

Ken Cummins, Samantha Hadden, and Peggy Wilzbach, Humboldt State University

Abstract: The feeding efficiency of juvenile salmonids on invertebrate drift was studied in the field and in experimental flumes under varying conditions of turbidities and ratios of organic to inorganic particle concentrations. Field observations were made by snorkeling in 200 m reaches of North and South Forks of Caspar Creek (Mendocino Co.), and in Prairie and Little Lost Man creeks (Humboldt Co.) on six sampling events encompassing a range of stream discharges and turbidities. At each event, individual fish were located and observed over a 3 minute period, with the number of prey captures per individual fish recorded. Juvenile coho (*Oncorhynchus* kisutch) and steelhead trout (*Oncorhynchus mykiss*) were subsequently captured and foregut contents were sampled by gastric lavage. Feeding rate and biomass of invertebrate prey sampled from the foreguts of juvenile salmonids declined throughout the range of turbidities sampled (4-50 NTU). Feeding rates of juvenile steelhead trout were also measured in artificial stream channels in which individuals were offered live prey under differing levels of suspended sediment concentration and organic to inorganic particle ratios. Feeding trials were conducted at low (4-30 NTU) and high (42-68 NTU) levels of suspended sediment concentration, and three different organic to inorganic particle ratios (75% organic, 50 % organic, and 25% organic). Foraging efficiency of the trout decreased significantly at higher levels of suspended sediment concentration, but not among ratios of organic to inorganic particles. In both field and laboratory studies, fish continued to capture prey at turbidity levels in the range of 40-50 NTU's, albeit at reduced foraging efficiency.

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The Role of Organic Suspended Sediment in Turbidity Studies

Mary Ann Madej, US Geological Survey

Abstract: Many hydrologic studies of suspended sediment and turbidity assume that all the sediment in the water column is inorganic in nature. Nevertheless, in forested watersheds, organic suspended sediment can contribute greatly to turbidity, especially on the early rising or late falling limbs of hydrographs. Organic particles are less dense than inorganic particles, so they can remain suspended in the water column longer, and can affect light attenuation throughout the recessional limbs of the hydrograph. Suspended sediment samples from four streams in redwood-dominated basins in north coastal California were analyzed for their organic content through loss-on-ignition tests. At turbidity levels less than 30 NTU, the organic fraction of suspended sediment samples was commonly greater than 40 percent by weight. This fraction decreased to about 10 percent at turbidities greater than 100 NTU. The relationship between organic content and turbidity was significantly different in an old-growth redwood basin than in a second-growth basin. Upper Prairie Creek, a stream with a wide floodplain dominated by old-growth redwoods, consistently had the highest organic content of the four sampled sites. These results indicate that for streams with heavily forested riparian zones, both organic and inorganic components of a suspended sediment sample should be determined.

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It's a Long Way From Reactive Distance to Populations: Estimating the Consequences for Fish of Variation in Turbidity Regimes

Bret Harvey, USFS Redwood Sciences Lab

Abstract: Turbidity can directly affect fish by causing: 1) mortality; 2) sub-lethal physiological changes; 3) changes in predation risk; and 4) changes in the ability to feed visually. However, linking these effects on individuals to population-level outcomes poses a challenge, because a variety of additional processes influence population-level results. For example, while high turbidity reduces the ability of fish to react to and capture drifting prey, reliance of fish on drifting prey may vary. Also, any variation with turbidity in the relative concentration of prey would influence feeding success, but few data address this issue. A modest amount of field data suggest that trout can continue to feed during periods of high turbidity, suggesting that at the reach scale, food concentration may increase during high-flow, turbid conditions.

Changing turbidity regimes often coincide with changes in other processes linked to elevated sediment transport and storage, and these can also have important consequences for fish. For example, elevated sediment transport and aggradation of fine sediment in stream channels may alter: dry-season surface streamflow, the extent of streambed scour, production of aquatic invertebrates, and thermal regimes. Therefore, useful estimates of the population-level consequences of turbidity may need to incorporate these additional effects. Individual-based models of stream fish populations, which can include the kinds of effects described above along with temporal variation in key physical variables (turbidity, temperature, streamflow), probably provide the most promising approach to this challenge. Individual-based models of trout incorporating turbidity's effects on reactive distance and predation risk suggest that observed variation in turbidity regimes among streams in northwestern California could have strong consequences for fish. However, application of such models remains hampered by uncertainties, including several linked to food availability.

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A Review of Instrumentation, Data Collection Methods, and Quality Assurance Procedures

Rand Eads, Redwood Sciences Laboratory, USFS

Abstract: Establishing a new gage site for the measurement of turbidity and suspended sediment can be technically challenging, but most sites can be successfully measured after making minor adjustments to the procedures and instrumentation during the initial phase of data collection. Highly erosive watersheds, however, demand a higher level of technical skills and fortitude to achieve success. Cuneo Creek, a 10.8 km^2 tributary to Bull Creek, in Humboldt Redwoods State Park, near Weott California, is an example of a gravel-bedded stream that produces large sediment loads in a watershed with steep topography and very erosive soils. High frequency sediment pulses from hillslope failures and floodplain erosion are often poorly related to water discharge. In addition, elevated sediment transport rates create unstable bed forms through the process of aggradation-degradation making it nearly impossible to establish a stable stage-discharge relationship. Shallow flow depths and velocities of 3.7 m/s or more create turbulent conditions that complicate sensor deployment and sample collection.

A Turbidity Threshold Sampling (TTS) station was installed during February 2004, utilizing a cable-mounted sampling boom, a DTS-12 turbidity sensor, an in-stream pressure transducer for measuring stage, and two automatic pumping samplers. The cable-mounted boom can be adjusted both vertically and horizontally to reposition the turbidity sensor and sampler intakes within the measurement cross-section, but this must be accomplished manually by field personnel. Changes to the streambed elevation during runoff events resulted in the loss of data when the boom became stranded on newly formed sediment bars. It is not uncommon for the streambed elevation to change by 1 m or more during a moderate runoff event. During such an event the stream bed scoured, and the steel conduit protecting the pressure transducer sheared in half, resulting in the loss of stage data. The pressure transducer was replaced by a non-contact ultrasonic sensor mounted from the bridge. When stream velocities were above 2.5 m/s the boom hydroplaned on the water surface, overcoming the gravitational force of the counter weight placing the sensor near the water surface. We replaced the cable-mounted boom with a depth-proportional boom mounted to a large boulder in the thalweg of the channel. The sensor and sampler intakes remained submerged because they were located in the scour hole created by the boulder. The turbulence in the scour hole produced a nearly continuous entrainment of bubbles near the optical sensor resulting in noisy turbidity data and erratic sample volumes. Finally, this boom was replaced by a longer boom to position the sensor and intakes farther downstream from the source of turbulence.

Turbidities exceeding the range of the sensor (approximately 2000 FNU) are common during larger events. The sampling logic in TTS program was modified to control two pumping samplers, providing additional sample bottles for fixed-time sampling when the turbidity exceeded the sensor's range. A subset of samples collected within the sensor's range, and all samples collected above the sensor's range, were measured in the laboratory with a Hach 2100AN turbidimeter. During extreme transport events the highest measured laboratory turbidity was 7485 NTU, and the highest measured SSC (1.0 µ filter) was 9194 mg/l. Sand fractions (> 0.63 µ) were determined from a subset of all pumped samples. The average sand fraction was 1.7%, and maximum was 14% of the total SSC. Instantaneous discharge measurements at the gage site were well correlated (R^2=0.95) to the continuous discharge records at the USGS Bull Creek gage, 4.4 km downstream. Although a stage-discharge rating was not developed for Cuneo Creek, lag periods were calculated from the stage peaks and applied to the Bull Creek discharge data to produce estimated 10-minute discharge values for Cuneo Creek.

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USGS Improves Turbidity Reporting Procedures

Timothy G. Rowe, US Geological Survey

Abstract: Water-resource managers commonly measure turbidity to help regulate drinking water clarity, monitor the transport of sediment and the impact of development on natural resources, and for other issues where water clarity affects environmental health. In collaboration with the public and private sectors, the USGS in 2004 improved the system used to report turbidity information.

The overhaul was spurred by the need for consistent and comparable reporting of turbidity measurements within the USGS and by other collectors. Advances in technology also spurred the improvements for measuring turbidity.

The USGS and its partners, including ASTM International, established a suite of units to report turbidity data. The new system will improve the quality and comparability of reported data and will reduce the variability of such data in the USGS and other databases. Turbidity information is often used by recreational boaters and fisherman, water treatment industries, resource managers, and environmental groups.

Technological advances have introduced a variety of turbidimeters designed to meet different water-clarity objectives. Because of differences in instrument design and light source, these various meters respond differently to color, particle size distributions, and/or particle concentrations in the water. The result is that different meters do not necessarily yield comparable data. Effective October 1, 2004, the USGS implemented an information-rich set of procedures that identify the type of turbidimeter used for measurements that are reported in the USGS National Water Information System (NWIS).

USGS data-collection and data-reporting procedures for turbidity, and associated references, are online at http://water.usgs.gov/admin/memo/QW/qw04.03.html (Office of Water Quality Technical Memorandum 2004.03) and in the USGS National Field Manual for the Collection of Water-Quality Data, Chapter 6.7, Turbidity http://water.usgs.gov/owq/FieldManual/Chapter6/6.7_contents.html).

The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

(from USGS News Release, "USGS Improves Turbidity Reporting Procedures", dated December 1, 2004, http://www.usgs.gov/newsroom/article_pf.asp?ID=302)

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Challenges and Opportunities in Pooling Turbidity Data

Randy Klein, Redwood National and State Parks

Abstract: Turbidity as an indicator of water quality has been criticized for being a 'non-scientific parameter', but its use persists, and even grows in terms of the number of stream locations where turbidity data are being collected and the array of equipment available for collecting it. Use of turbidity as a surrogate for suspended sediment concentration is well-established, but suspended sediment data are and expensive to collect, whereas turbidity can be feasibly collected using automated and manual methods. This presentation will discuss some practical aspects of monitoring turbidity and suspended sediment in streams with the overlapping objectives of: 1) collecting meaningful turbidity data cost-efficiently, and 2) incorporating program elements that can increase the opportunities for pooling turbidity data.

Designing a monitoring program for collecting meaningful turbidity data requires some understanding of both the spatial and temporal variations in turbidity. An automated station can, if all goes as intended, collect virtually continuous data that are internally consistent, i.e., turbidity values within that record are proportional to one another and to suspended sediment concentration. However, they only represent what occurred at a single location in the stream network. If we want to determine, for example, primary sediment source areas contributing to what our continuous station records, we need upstream data. For most of us, we cannot afford to install and maintain continuous stations on every tributary in a watershed. Manual sampling can help sort out spatial and temporal variations cost-efficiently, but only if done with some prior planning based on a knowledge of how streams behave during and after storms. Examples will be given of simulated manual sampling and a trial of a manual sampling effort that shows that how a well-directed manual sampling program can illuminate some differences among streams.

Pooling data turbidity allows analyses that can help address important scientific and management-related issues, such as the effect of geology or basin size on water quality, or the relative sensitivity of different basins to land use, and the ability to confidently describe such relationships increases directly with the number of basins or sampling sites included. However, to compare turbidity data from different streams, it is necessary to either: 1) collect all data with the same instrument, or 2) convert all data to a common basis for comparison. The variety of turbidity measuring equipment presently in use precludes the first option, leaving the second option as the only viable means for pooling turbidity data. Examples will be given of the usefulness of using conversion methods to compare turbidity data collected with different devices.

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Using Multi-Parameter Water Quality Instruments to Perform Continuous Monitoring

Bob Nozuka, California Dept. of Water Resources

Abstract: The Department of Water Resources has been collecting chemical water quality data throughout the State for over 50 years. Historically, water quality monitoring involved taking grab samples for lab analysis. Recently, the Department started using continuously monitoring multi-parameter water quality instruments. The Central District currently operates 14 multi-parameter water quality stations that collect data every 15 minutes.

These instruments provide the following benefits over other sampling techniques:

1. Improves our accuracy in understanding water quality conditions as well as the variables that influence water quality changes over time and event.
2. Reduces personnel commitment and overall cost for a comparable level of monitoring.
3. Portable, self contained and can easily and quickly be deployed in any aquatic environment.
4. Requires minimal environmental permitting based on installation method.
5. Continuously monitors up to 10 chemical constituents and log the collected data in memory.
6. Capable of telemetering the data either by radio, GOES or cell phone.
7. Relatively easy to maintain and service.
8. Data can be easily imported into a flat file or database.

The Department uses the data gathered by these instruments to help plan the distribution of water to over 22 million Californians and to over 800,000 acres of agricultural land. Three prominent areas where the multi-parameter instruments are currently being used are: the south Delta, Rock Slough in the Delta and the Truckee River.

The data collected in the south Delta is used to understand the water quality impacts due to the operation of the State Water Project as well as seasonal installation of the temporary rock barriers in Old River, Middle River and Grantline Canal.

The Rock Slough water quality data is used to monitor the effects of the State Water Project on EC levels in Rock Slough. Rock Slough is the source water for the Contra Costa Canal which provides M&I water to portions of the East Bay.

The water quality data collected on the Truckee River is used to establish a baseline water quality condition as well as to provide turbidity data to help establish a sediment load to turbidity relationship.

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CASE STUDIES IN MONITORING SUSPENDED SEDIMENT AND TURBIDITY

Connecting Watershed Sediment Budgets and Sediment Yield With Turbidity Monitoring Case Studies From PALCO Lands on the North Coast of California

Kate Sullivan, PALCO

Many rivers on the North Coast of California are currently listed as impaired for sediment on the State's 303D list. Impairment within the Clean Water Act requires that a TMDL process be applied to the watershed that identifies sediment sources and allocates loading by erosion processes and land ownership to achieve the overall water quality targets. Sediment budgeting techniques have been used to arrive at load allocations and point to the causal mechanisms of sediment in relation to natural and anthropogenic sediment. Sediment sources and load allocations are usually expressed as sediment yield (e.g., tons per square mile), while water quality conditions are related to turbidity in basin standards. The relationship between these two characteristics is not usually expressly known. Following load allocation, an implementation plan is designed to lower sediment rates to meet the watershed allocation targets. Many watersheds on the North Coast of California are currently in some stage of this TMDL process.

PALCO has continuously monitored the characteristics of suspended sediment at a number of locations within watersheds for several years where sediment source assessments using sediment budget techniques have also been conducted. Turbidity and streamflow are continuously measured augmented by frequent physical sampling of suspended sediment. These data allow computation of the annual suspended sediment yield from the watersheds. Thus, the premise that there is a relationship between the rate of erosion processes and the amount of sediment transported in the system can be evaluated. Inevitably, the sediment budgets yield an average yield for some period of time. In this paper, results of sediment source assessments are compared to measured sediment yield. During the interval of measurement, a number of sediment reduction measures have been implemented within the watersheds, and a significant geomorphic event has occurred. The challenge of the monitoring data is also to read the suspended sediment information for trends that may indicate that sediment sources are reduced through implementation of the management plans.

Generally, sediment budgets are reasonably close to measured sediment yield, and trends apparent in water quality monitoring are generally consistent with observed changes in erosion sources. These results provide some credence to the principle that managing sediment sources ultimately relates to water quality. When the two approaches are applied together, the picture of watershed sediment yield is clearer and somewhat more certain than when applying one technique alone.

Grab Sample What-ifs in the Context of Event-Based Suspended Sediment Monitoring on Little Creek, Swanton Pacific Ranch – Cal Poly

Dr. Brian C. Dietterick, Director, Swanton Pacific Ranch, Cal Poly – SLO
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Suspended sediment monitoring, or the use of turbidity as a surrogate, as an indicator of mass wasting or other surface erosion that is attributable to improper land management practices has been documented in a number of watershed-scale experiments. Yet, the data necessary to detect cause and effect often requires years of costly monitoring using sophisticated equipment and training personnel in laboratory analyses and field instrument operation. It has proven to be difficult to successfully collect all parameters necessary for determining event-based sediment responses without a significant commitment of resources and personnel. The use of grab samples is often prescribed for ensuring regulatory compliance associated with timber harvest plans. These strategies have resulted in more questions than answers and have led to doubts regarding the scientific validity of some of the approaches. Event-based turbidity and suspended sediment data is collected for Little Creek on Cal Poly's Swanton Pacific Ranch to determine the success of a pre-harvest calibration under widely varying climatic conditions and landslide–dominated sediment influences. A comparison is made between the event-based suspended sediment and turbidity data for Little Creek to data representing a number of hypothetical grab sample scenarios. The evidence of inter- and intra-station variability warrant intensive sampling for upstream/downstream strategies where multiple sources of sediment delivery exist.

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Suspended-Sediment Loads to Lake Tahoe

Andrew Simon, USDA-ARS National Sedimentation Laboratory

Activities such as logging, road construction, mining, overgrazing and urbanization have led to degradation of land and water resources and threaten to do irreparable damage to Lake Tahoe. Concerns over lake clarity have been partly attributed to the delivery of fine-grained sediment emanating from upland and channel erosion. Research was designed to combine detailed geomorphic and numerical modeling investigations of several representative watersheds with reconnaissance-level evaluation of approximately 300 sites to determine sediment loadings from the 63 watersheds draining to Lake Tahoe.

Suspended-sediment loads and yields vary over orders of magnitude from year to year, from west to east and north to south across the basin. Median annual suspended-sediment loads for index stations range from about 2200 tonnes/yr (T/y) from the Upper Truckee River to 3 T/y from Logan House Creek. The largest annual contributors of sediment are in decreasing order, Upper Truckee River (2200 T/y), Blackwood Creek (1930 T/y), Second Creek (1410 T/y), Trout Creek (1190 T/y), Third Creek (880 T/y) and Ward Creek (855 T/y). Data from Second and Third Creeks may be somewhat misleading because of a short period of data collection in the case of the former, and the fact that data collection occurred during major construction activities in these basins. In fact, analysis of suspended-sediment transport ratings with longer periods of record (17 to 20 years) show that sediment loads from the northeast streams have significantly decreased across the entire range of flows. The lowest contributors of suspended sediment from index stations, in increasing order are Logan House (3.0 T/y), Dollar (4.6 T/y), Quail Lake (6.4 T/y), Glenbrook (8.9 T/y), and Edgewood Creeks (21.3 T/y).

Fine-grained loads show a similar pattern as total loads with the greatest contributors being the Upper Truckee River (1010 T/y), Blackwood Creek (844 T/y), Trout Creek (462 T/y) and Ward Creek (412 T/y). The lowest contributors are Logan House Creek (2.3 T/y), Dollar Creek (2.6 T/y), Quail Lake Creek (3.2T/y) and Glenbrook Creek (7.0 T/y). In terms of fine-grained loadings per unit area, Blackwood, Third, and Ward Creeks, all disturbed streams have the greatest fine-grained suspended-sediment yields at 21.5, 20.2, and 16.4 T/y/km^2.

Sediment yields were also used to discriminate between loadings from disturbed and undisturbed watersheds. Although the western streams produce more sediment per unit area than eastern streams, General Creek is considered a "reference" stream because of a lack of recent human intervention. Sediment yield from General Creek is about 9 T/y/km^2. In contrast, yields from Blackwood and Ward Creeks, streams disturbed to different degrees by human activities are about 66 and 34 t/y/km^2, respectively. On the eastern side of the lake, relatively undisturbed Logan House Creek produces 0.6 T/y/km^2 compared to the developed Edgewood Creek watershed that produces about 3 T/y/km^2. The effects of human disturbance on streams draining the northeast part of the Lake Tahoe watershed (Third, Second and Incline) are shown to have produced orders of magnitude more sediment in the 1970's (during construction and development) than at present.

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Judd Creek Watershed Study: Results, Measurement Protocols and Assessment Methods

Cajun James, Sierra Pacific Industries

Abstract: Throughout the last decade, questions emerged surrounding the effectiveness of forest management practices in California to adequately protect water quality. In order to determine the potential impact of timber management operations on water quality, the Board of Forestry and Fire Protection (BOF) has established cooperative peer reviewed research projects with various landowners. My presentation will contain information and results from the Judd Creek Watershed Study, which is one of these cooperative watershed scale experiments between Sierra Pacific Industries, the California Department of Forestry and Fire Protection and the Central Valley Regional Water Quality Board.

The objective of this monitoring project is to examine the response of water quality in Judd Creek due to intensive upland forest management activities. Changes in the spatial and temporal variability of stream flow, turbidity, and suspended sediment transport regimes for Judd Creek will be characterized before and after timber harvest operations to determine the effect of timber harvest operations on water quality. In addition, the effect of stream crossing reconstruction, road abandonment, and new road construction on turbidity above and below treatment sites will be evaluated. Data collected from five water quality stations for water temperature, discharge, turbidity, suspended sediment, pH, conductivity, and dissolved oxygen, plus grab samples for the same parameters, and photo points will be included for analysis. This project has five phases and the timeline is from November 2004 to winter 2010. In Phase One (2004-2006) baseline data collection commenced. In Phase Two (2007) road and culvert work will be performed. In Phase Three (2008) data will be collected with no other treatments. In Phase Four (2009) forty-one units ranging in size from 10 to 26 acres will be chipped and clear – felled harvested. In Phase Five (2010+) monitoring data will continue to be collected.

Water Quality data from winter 2000 to April 2005 will be used as a presentation basis. Preliminary results of relationships between turbidity, suspended sediment concentrations, stage, and rainfall will be shown and used to illustrate unique features of the study areas as well as challenges facing researchers in developing robust field measurement protocols and quantitative assessment methods.

Results from this monitoring project will contribute valuable information to regulators, forest landowners, and the public with regards to forest management operations and water quality for inland California watersheds.

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Turbidity Tales at Multiple Scales:
Water Quality Monitoring on the Hawthorne Ownership, Mendocino County

Stephen P. Levesque, Campbell Timberland Management

Abstract: Campbell Timberland Management, LLC ("Campbell") manages approximately 184,000 acres of coastal forestlands in Mendocino County owned by the Hawthorne Timber Company, LLC ("Hawthorne"). Currently there are two separate turbidity and suspended sediment transport studies in progress on the Hawthorne ownership. Each study is collecting water quality and quantity data at different spatial and temporal scales in order to meet project objectives.

The first of these studies started in WY2002 within the South Fork Ten Mile River watershed. A USEPA TMDL for sediment was prepared in 2000 for the larger Ten Mile Watershed. The supporting sediment source analysis for the TMDL was based primarily on remote sensing data with little field verification. As Hawthorne owns approximately 90% of the SF Ten Mile watershed, Campbell is collecting data to validate the estimates of sediment delivery published in the TMDL. A secondary project objective is to establish a long-term trend-monitoring program at the planning watershed scale. In accordance with the quality control and quality assurance program, streamflow and sediment transport measurements were collected at seven sites ranging in drainage area from 3.96 mi^2 (planning watershed tributary) to 37.5 mi^2 (lower mainstem). Peak annual discharges range from 187 cfs at the planning watershed scale to 2,630 cfs in the mainstem. Peak annual turbidities and computed annual suspended sediment loads ranged from ~130 NTU to ~1000 NTU, and from 590 tons to 18,962 tons, respectively. Suspended sediment loads in the mainstem have exceeded the average suspended sediment load calculated for the TMDL in the last three years of this study.

The second study is located in the South Fork Wages Creek watershed. Project objectives are to evaluate the relative importance of sediment generated by timber operations and the effectiveness of current road construction and logging practices to maintain beneficial uses relative to legacy sources and background erosion rates. To effectively conduct water quality monitoring in mountain drainage basins at the project (THP) scale, it is necessary to establish pre-harvest (background) water quality conditions. This alone renders the idea of quantitative measurement programs of turbidity at the project scale extremely problematic. In the absence of pre-logging water quality data, Campbell proposes to treat the South Fork of Wages Creek as an experimental watershed, collecting a minimum of three to five years of pre-treatment data to establish "ambient" conditions. At the end of this pre-treatment period, Campbell will implement a Timber Harvest Plan consistent with standard operational practices followed by five to seven years of post-treatment monitoring. Streamflow and sediment transport measurements are collected at seven sites ranging in drainage area from 0.1 mi^2 to 1.4 mi^2. Peak annual discharges and turbidities for WY2004 ranged from 5.3 cfs to 70 cfs and from ~12 NTU to ~22 NTU, respectively. In future water years, monitoring data from the study area in SF Wages Creek will be compared to similar data collected immediately upstream from the Wages Creek estuary.

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Why Monitor Turbidity: Is There a Connection Between Turbidity and Fish Populations?

Matthew House, Lowell Diller and Brian Michaels, Green Diamond Resource Co., Korbel, CA

Green Diamond Resource Co. has been developing an aquatic monitoring program for its coastal northern California timberlands over the last 10 years. The overall goal of the program is to develop an integrated monitoring approach that focuses on a suite of aquatic response variables that has the greatest potential to be impacted by timber management, are of critical importance to an aquatic resource and are conducive to monitoring. One of these response variables is turbidity/suspended sediment. We currently operate a variety of water quality monitoring stations that measure stage and turbidity and some that collect water samples to determine suspended sediment concentrations (Turbidity Threshold Sampling). The literature suggests that elevated turbidity/suspended sediment can negatively affect fish in a variety of ways such as reduced feed, increased stress, displacement and reduced growth and survival. Five TTS stations are operated where Green Diamond also collects biological information such as summer juvenile population and outmigrant smolt estimates. The combination of water quality metrics and various biological variables provides an opportunity to examine the possible effects of turbidity/suspended sediment on fish. Green Diamond is also cooperating with a graduate student field study that is examining the foraging success of salmonids at various levels of turbidity.

For a variety of reasons, the speakers' PowerPoint presentations will not be provided in the conference registration folder. The conference organizers respect PowerPoint presentations as the intellectual property of their presenters. Additionally, some of the information presented is part of a project in progress and some data is yet to be published. **Please respect that everyone is looking forward to a busy upcoming field season and find any presented information you require from the websites as indicated below or from the references above.**

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